The **CERCular**

Coastal Engineering Research Center

Vol CERC-98-2 July 1998

The Punaise: An Innovative Submerged Dredging System

by Gregory L. Williams[1] and Kris Visser[2]

The Innovative Dredging Equipment and Processes Technology focus area of the U.S. Army Corps of Engineers Dredging Operations and Environmental Research program is being conducted at the U.S. Army Engineer Waterways Experiment Station (WES). This focus area will demonstrate and document emerging dredging and disposal technologies available from both domestic and foreign dredging interests for application to Corps dredging projects. Most advances in the dredging industry are modifications to existing equipment. Very infrequently, a new dredging concept is developed. The *Punaise* is new dredging technology which has not yet operated in the United States. The first *Punaise* was designed for silt removal and used in 1991 in The Netherlands. Since then, a second system has been constructed to transport sand for beach nourishment activities. PinPoint Dredging Company, a partnership of J. G. Nelis, Ballast Nedam Dredging, and Boskalis International, operates the *Punaise* and most recently used it at a beach nourishment project on the Dutch coast during 1996.

The *Punaise* (Dutch for "thumbtack") is a remotely operated, watertight submerged dredge that resides on the seafloor, pumps sediment without impact to navigation, and is not affected by storms. Because it is located on the seafloor, it is very tolerant of adverse surface wave action, which allows it to operate in all types of weather and sea state conditions. The *Punaise* is connected to a shore station by an umbilical, which serves not only as the communication connection but also as the discharge line through which the dredged slurry is pumped. The entire dredging process, including sinking and floating (i.e., filling and emptying ballast tanks), is controlled from the shore station by one person. The *Punaise* can thus operate for long periods with relatively low labor costs. Maximum flexibility in sediment removal is attained through repositioning the *Punaise* at the dredging site from time to time with the help of a tug.

This paper is not an endorsement for any particular technology or dredging company, but is intended to identify a technology with potential application in the United States.

Operational Principle

The *Punaise* operates under the principle of deep dredging (i.e., putting the dredge pump as close to the sediment intake as possible). In so doing, the *Punaise* always requires an embedded support that must extend below the suction intake for vertical stability during dredging. Figures 1 and 2 show the two existing *Punaises* (PN250 and PN400, respectively), which contain a dredge pump, electric motor, instrumentation, suction intake, and vertical support. Specifics for each model are shown in Table 1.

During setup prior to dredging, the shore station is established and the umbilical is floated to the dredging site. The *Punaise* is then connected to the umbilical and positioned at the appropriate location for sinking to the seafloor. Once positioned, the ballast tanks are filled and the *Punaise* settles to the

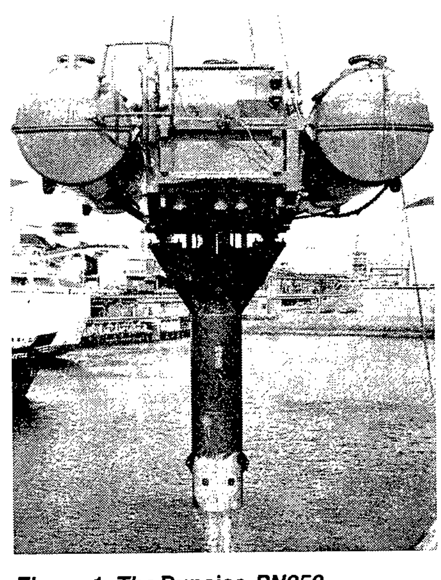

Figure 1. The **Punaise** *PN250*

[1] Research Hydraulic Engineer, Coastal and Hydraulics Laboratory, WES, Vicksburg, MS.

[2] Project Engineer, PinPoint Dredging Company, P.O. Box 802, 2003 RV Haarlem, The Netherlands.

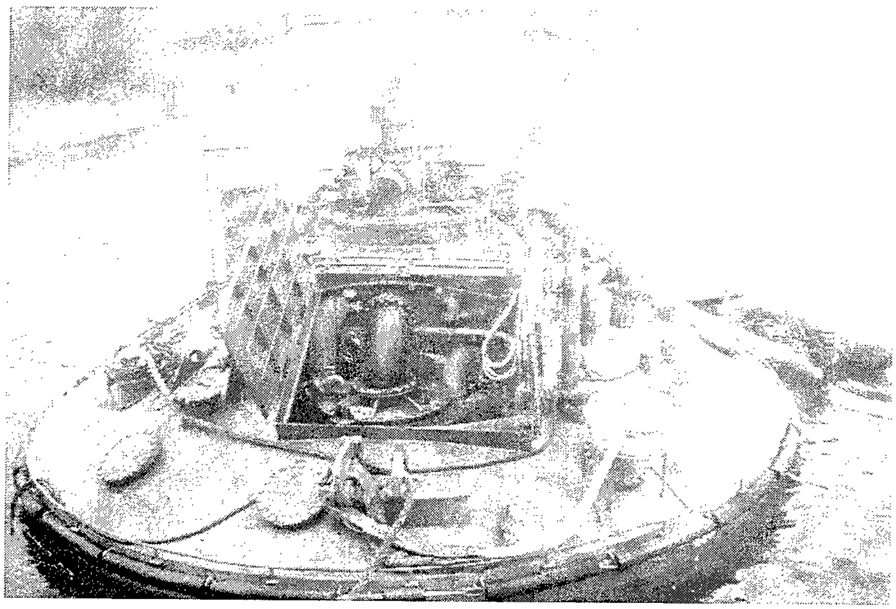

Figure 2. The Punaise *PN400*

Table 1. Punaise Design Specifics		
	PN250	PN400
Width	7.8 m	8.5 m
Height (without suction pipe)	3.1 m	6.0 m
Height (with suction pipe)	8.5 m	8.7 m
Draft	7.5 m	6.5 m
Working depth	30 m	40 m
Required sediment thickness Initial production Maximum production	 6 m 8 m	 7 m 10 m
Pump capacity	800 cu m/hr @ 87 psi	2,400 cu m/hr @ 116 psi
Discharge pipe diameter	4.0 cm	6.2 cm
Weight	52 tons	105 tons

bottom. Fluidisers are then activated, which allows the vertical support (an extension of the suction pipe) to settle into the sand bottom. When the suction intake reaches the level of the bottom, dredging begins. As material is removed, a crater or pit is formed with the *Punaise* located at the lowest point. Dredging continues and the crater/pit size grows (*Punaise* settles further into the bottom) until either the desired dredging depth is reached or resistant bottom features (e.g., bedrock, clay) prevent further settling.

Energy and Data Supply

Electrical power is supplied by two diesel-driven generators located at the shore station on the beach. The total installed electrical power is approximately 1,200 kW, with 800 kW/3,000 V used for the sand pump electric motor and 150 kW/660 V used for the auxiliary equipment. The umbilical is composed of 11-mm core diameter electrical cables, which provide a relatively cheap and flexible system so that future changes in working distance and/or electrical power can easily be adapted.

Remote Control Dredging

The unmanned dredge is controlled by one operator from the shore station using standard personal computers for visualizing and controlling all the processes for signal input and output. All signals (420 digital and 105 analog) are updated and logged every second. All processes (except diving and floating) are fully automated so the operator only tracks operation status, which is visualized on a monitor. Diving and floating remain manually controlled because the various external factors require an experienced operator. The dredging process is displayed on a separate monitor, which includes a window showing the last 10 min of operation to track trends. Additionally, the complete filling of the 1,500-m discharge pipe is shown so the operator can determine the specific critical flow based on the mass of sand in the pipe. The primary variable which the operator can influence is density. Using water jets at the suction mouth and two bypass valves located immediately before the pump entrance, the operator can easily adjust the sand/water mixture with only a few mouse clicks at the computer. Another monitor shows the status of shore-based equipment (generators, air compressors, and fuel supply). Finally, daily reports showing production results, equipment status, fuel consumption, and *Punaise* movements and location can be produced at the end of each day's operation.

In the event of a fiber-optic failure where communication between the dredge and shore station is lost, the dredge can operate autonomously via a special program in the dredge. If the connection fails, the dredge automatically opens all the bypass valves and pumps clean water to shore, thereby removing all of the sand from the discharge pipe. To retrieve the dredge, the operator can supply air at 70 psi to the *Punaise* through one of two air hoses in the umbilical, which allows the dredge to empty its ballast tanks and rise to the surface.

Beach Replenishment Projects in The Netherlands

The dredge *Punaise* PN250 was initially used to remove 600,000 cu m of silt per year for 2 years from Flushing Harbour in The Netherlands. The system proved to be so effective that a demonstration contract was signed between the Dutch Ministry of Public Works (DMPW) and the contractor (J. G. Nelis) to conduct beach nourishment projects. The decision was made to construct a bigger and more powerful dredge (*Punaise* PN400) specially suitable for pumping sand from a borrow pit at sea in the coastal zone. *Punaise* PN400 was constructed primarily for three projects, all on the central North Sea coast west or northwest of Amsterdam. Details of these projects are summarized in Table 2.

Production

For the 1994 projects, the DMPW monitored the effects of a temporary sand rehandling pit in front of the coastline at -7.0 m mwl. The monitoring program indicated that negative effects on the coastal morphology and the macrobenthic community on the seabed adjacent to the borrow pit area were either small or immeasurable. Turbidity levels measured in the breaker zone did not exceed the usual background values and there was no evidence of any movement of the pit in any direction. The *Punaise* was allowed to create its own pit to meet the total quantity to be dredged with no limitation placed on pit size. Total dredging depth was limited to -25.0 m mwl, and the resulting pit was kidney-shaped.

For the project conducted in 1996, the *Punaise* was restricted to work in a 100-m by 60-m area at a depth of -25.0 m mwl. The contours of the rehandling pit at the original depth were 250 m by 150 m. After removing 150,000 cu m from the pit, the *Punaise* received dredged material dumped from a hopper dredge for onshore pumping.

The 1994 projects were conducted in April and May during calm/normal weather conditions. The average hourly productions per day are shown in Figures 3 and 4 for Bloemendaal and Zandvoort, respectively. In October and November 1996, the DMPW initiated the beach nourishment project at Heemskerk to test the performance

Table 2. *Punaise* Projects in The Netherlands

	Bloemendaal	Zandvoort	Heemskerk
Year	1994	1994	1996
Volume	255,000 cu m	350,000 cu m	475,000 cu m
Length of replenishment	2,500 m	2,000 m	1,600 m
Volume per length	103 cu m/m	175 cu m/m	297 cu m/m
Fill elevation	+ 3.5 m mwl	+ 3.5 m mwl	+ 4.0 m mwl
Slope	1:30	1:30	1:30
Maximum pumping distance	2,700 m	2,000 m	1,900 m
Length of submerged pipeline	1,000 m	1,000 m	1,100 m

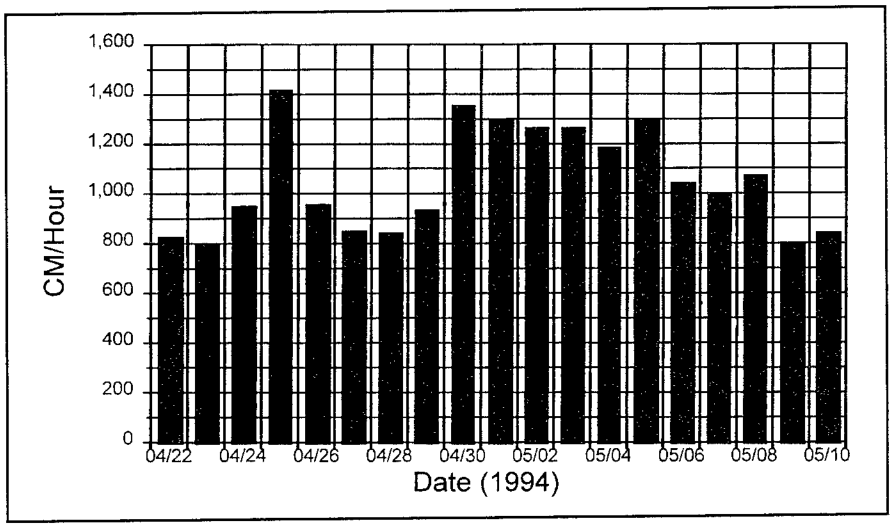

Figure 3. Average Punaise *hourly production by day at Bloemendaal*

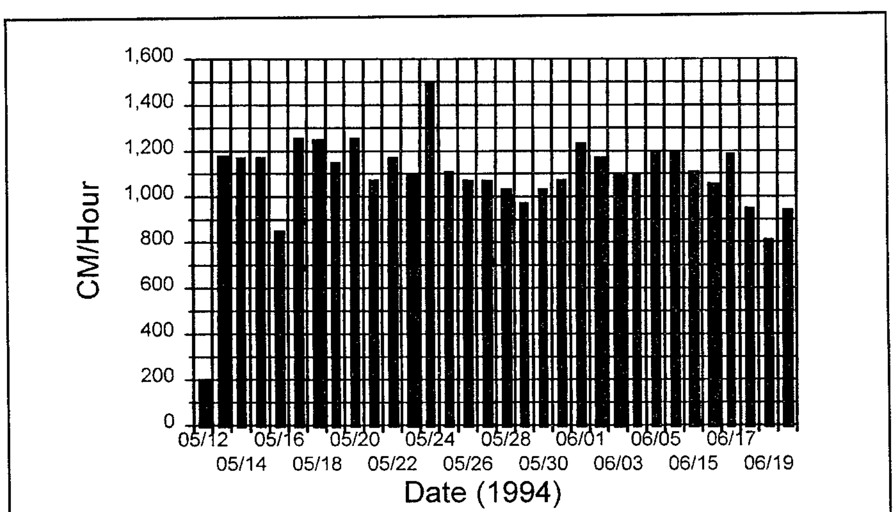

Figure 4. Average Punaise hourly production by day at Zandvoort

under heavy weather conditions. During the 2-week period from 1–13 November, the system was tested during a series of storms. A wave rider buoy located offshore recorded storm conditions approaching 10 on the Beaufort Scale, described as: (a) very high waves with long overhanging crests; (b) mean wind speed 52 knots; (c) probable wave height about 9.0 m.

During the first days of the storm, production increased because of an increasing pit production, and the pit slopes changed from 1:3 to 1:5 as a result of breaking waves. After dredging and pumping approximately 150,000 cu m from the pit, additional material was to be supplied by a hopper dredge near the beginning of the storm period. However, owing to the adverse weather conditions, hopper dredge operations did not begin until 13 November. This test thus showed the vulnerability of a continuous production if a hopper dredge and *Punaise* are used together when weather is uncooperative. Figure 5 shows the daily production of the *Punaise* during this time period.

Cost

To minimize cost for mobilization and installation, all of the equipment except the hull of the dredge is stored in containers and transported by ship to a harbor near the dredging location. Assembling of the discharge pipeline and umbilical, and establishing the units for control and power supply normally takes about 4 weeks. The unit cost for dredging the three demonstration projects conducted in The Netherlands was $4.71/cu m ($3.60/cu yd).

Punaise Operations in the United States

The State of New York and PinPoint Dredging Company planned to demonstrate the *Punaise* system at Shinnecock and Jones Inlets on the south shore of Long Island during January-February 1997. This demonstration was intended to investigate the feasibility of using the *Punaise* to conduct sand bypassing at structured inlets in the United States. A detailed effort to monitor equipment effectiveness, crater surveys, and beach surveys near the crater and placement sites was planned. Shinnecock and Jones Inlets each have chronic downdrift erosion problems, so the demonstration would have provided an opportunity to evaluate the technology as well as place much needed sand on the downdrift beaches. The demonstration was to have bypassed approximately 153,000 cu m from each inlet to the downdrift beaches. Assuming an equal distribution of mobilization/demobilization costs between inlets, total project costs were estimated at $810,000 for Shinnecock and $910,000 for Jones. These costs translate to respective unit costs of $5.29/cu m ($4.05/cu yd) and $5.95/cu m ($4.55/cu yd) at each inlet. Cores taken at each site indicated that no more than a 6.1-m-thick layer of clean sand was available for dredging at either site. Since this sand thickness was insufficient to support maximum production (see Table 1), the *Punaise* demonstration project was canceled. Although the PN250 (and possibly the PN400) could probably have dredged some sand, the location of a clay layer would have required frequent repositioning, thus reducing dredging efficiency and greatly increasing cost.

No other project has considered using the *Punaise* system for dredging in the United States. One reason for lack of U.S. work relates to issues associated with the Merchant Marine Act of 1920 (more commonly known as the Jones Act), which might have limited the ability of the *Punaise* to operate in waters of the United States since it is not a U.S. flagged vessel. Before the State of New York could enter into a contract to use the *Punaise* for bypassing at Shinnecock and Jones Inlets, the state had to seek a ruling from the U.S. Customs Service on whether the *Punaise* dredging system was prohibited by the Jones Act. In August 1996, the U.S. Customs Service issued a ruling on the legality of *Punaise* operations in the United States. The U.S. Customs Service decision is based on two requirements from the law, namely that to be prohibited, "...it must be engaged in dredging and must be a vessel." The U.S. Customs Service showed that the *Punaise* was indeed involved in dredging, but since it neither carried a crew nor merchandise, nor was it self-propelled, it could not be considered a vessel. Therefore, the *Punaise* is not prohibited by the Jones Act from working in the United States.

In 1996, the Dutch dredging companies J. G. Nelis, Ballast Nedam Dredging, and Boskalis International entered into an agreement for the exploitation of the Pinpoint

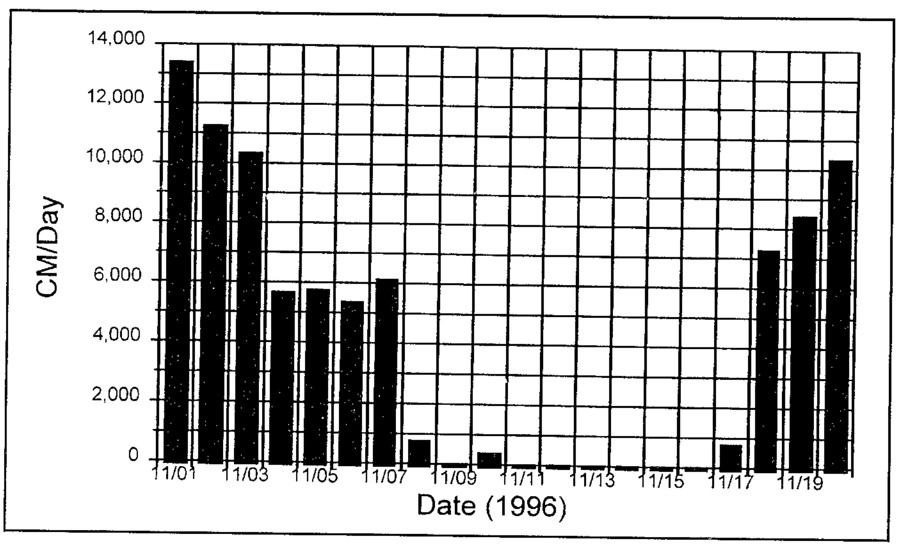

Figure 5. Average Punaise *hourly production by day at Heemskerk*

technology with the dredges *Punaise* PN250 and PN400. All three partners are working together in this agreement to develop and improve this innovative dredging method. Stuyvesant Dredging Company, New Orleans, Louisiana, fully owned by Boskalis International, is the primary contractor of the *Punaise* in the United States. Currently, there are plans to build a *Punaise* dredge (PN250) to specifically address dredging and bypass problems around the many inlets along the sandy U.S. east coast. PinPoint Dredging expects to execute the first demonstration project in the United States in 1998.

Conclusions

The *Punaise* is a new concept in dredging technology that allows dredging operations in and near navigation channels with minimal impact on ongoing navigation. Some of its advantages are as follows:

- Submerged system.
- Operated via remote control.
- Connected to shore by a communication/discharge umbilical.
- Requires only one operator.
- Automated operation.
- Has mobility for movement within a borrow area or to other locations.

Previous work in The Netherlands has proven the technology to be an effective system to dredge and pump material for traditional beach nourishment projects. The *Punaise* is also especially adept for working in storm conditions at relatively low costs. The *Punaise* is not restricted by the Jones Act for operations in the United States. Pinpoint Dredging is currently considering a design modification to allow better access to thicker sand layers in shallower waters.

Gulf of Mexico Wave Hindcast Update Completed

The WES Wave Information Studies (WIS) hindcast update for the Gulf of Mexico has been completed for an additional 18 years (1976-1993). Additionally, wave calculations for 1994 and 1995 yearly hindcasts have been appended onto the 18-year files to provide 20 years (1976-1995) of continuous wave information for 101 coastal stations in the Gulf of Mexico. The same 0.25-deg latitude-longitude computational grid was used for both the 18-year update and for the 1994 and 1995 yearly hindcasts. This grid is twice as dense as the 0.5-deg computational grid used for the original 1956-1975 hindcast. Hence, the 1956-1975 Gulf of Mexico stations 1-56 DO NOT correspond to stations 1-56 in the 1976-1995 update hindcast. Also, the effects of tropical cyclones were included in the 1976-1995 hindcast. The map at URL http://bigfoot.cerc.wes.army.mil/a0078.html and the latitude-longitude coordinate table at URL http://bigfoot.cerc.wes.army.mil/h009.html provide the locations of the 101 1976-1995 Gulf of Mexico output stations. Time-histories for the 1976-1995 period are recorded hourly rather than every 3 hr as in the earlier 1956-1975 hindcast.

The 1976-1995 time series for the 101 Gulf of Mexico stations can be downloaded from the Coastal Engineering Data Retrieval System (CEDRS) on the World Wide Web via anonymous FTP. Joint distributions (percent occurrence of wave heights and periods), mean and maximum wave heights stratified by month and year, and return periods of wave heights have been tabulated for each station. These statistical tables are also available via anonymous FTP. URL http://bigfoot.cerc.wes.army.mil/u057.html details the instructions for downloading either the time series computations or precomputed tables.

For further assistance, contact Mr. Doyle Jones, e-mail d.jones@cerc.wes.army.mil with questions pertaining to downloading/extraction of time series or tabulated statistics. Technical questions concerning WISWAVE (numerical model used for the 1976-1993, and 1994 and 1995 Gulf of Mexico hindcasts) should be directed to Dr. Lihwa Lin, e-mail l.lin@cerc.wes.army.mil

Geotextile Tube Structures for Wetlands Restoration and Protection: An Overview of Information From the National Workshop on Geotextile Tube Applications

by Jack E. Davis[1] and Mary C. Landin[2]

Background

In recent years, the U.S. Army Corps of Engineers (USACE) has increasingly used geotextile tubes to provide temporary or permanent breakwaters, especially when coupled with a goal of using dredged material for wetland restoration or other natural resource beneficial uses. The first application of geotextile fabrics for wetlands and habitat development occurred in the early 1970s in Galveston Bay, Texas, and later in Core Sound, North Carolina. Large nylon bags (12 ft x 4 ft x 3 ft) were filled in place hydraulically with sandy dredged material to form stacked breakwaters. By the mid-1980s, the Corps was testing and using 100-ft-long, 3-ft-diam Longard tubes made of low-tensile-strength geotextiles. These were all used in underwater situations to improve water quality, to provide surge protection, and to protect sea grass and other aquatic habitats. Their construction was awkward, and the tubes were very difficult to fill. They were not very stable, and their use declined.

In the early 1990's, USACE developed a renewed interest in evaluating and using custom-made geotextile tubes as containment dikes for the placement of dredged material. After placement, the tubes act as erosion protection structures for the dredged material, and for any intertidal wetlands that may develop. In some places, the tubes are being used as low-crested, reef-type breakwaters placed offshore of existing or newly restored wetlands.

The new interest in geotextiles tubes is twofold. First, they can be deployed relatively quickly, with several hundred feet being placed in a day. Second, they are relatively inexpensive, with cost being based largely on the application and when they are constructed. The tubes are delivered to the site either rolled up (Figure 1) or folded like an accordion. The tubes, which have ranged between 8 and 45 ft in circumference and anywhere from 100 to 1,000 ft long, are spread out along a desired alignment (long tubes are usually deployed a few hundred feet at a time). The tube is then filled with sediment, which is supplied to the tube in a slurry from a pump, usually from a dredge. Mobilization of the dredge is usually the largest cost in deploying a tube. In most projects, a dredge is probably already mobilized as part of a channel maintenance project. Therefore, mobilization of a dredge is usually not included in the cost of constructing the tube. In some recent projects in Texas, constructed costs were around $50 per linear foot of project. In one project, where a dredge had to be mobilized to fill a short tube, costs exceeded $200 per linear foot.

National Workshop on Geotextile Tube Applications

During the planning for use of geotextile tubes, many questions are raised about the best techniques for designing, deploying,

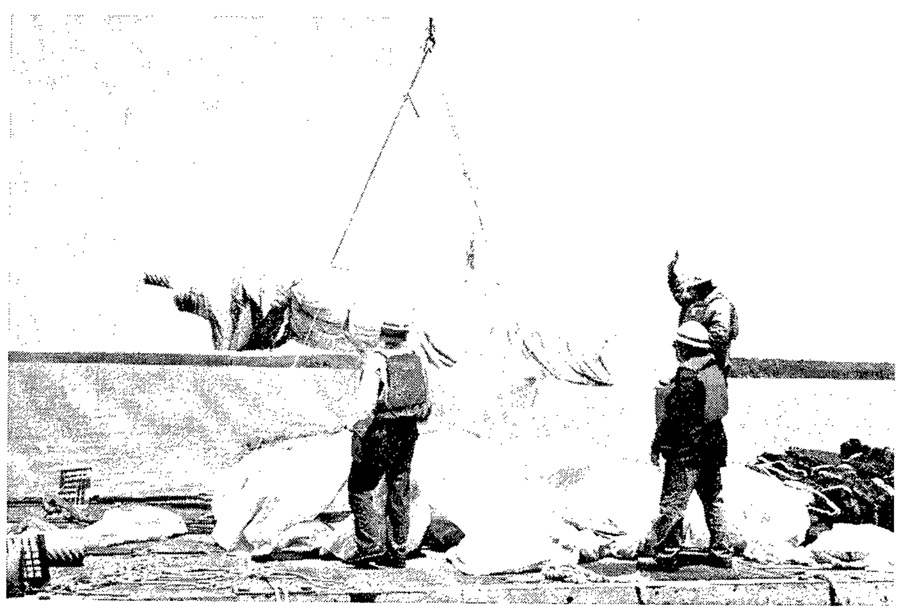

Figure 1. Geotextile tubes being delivered to project site

[1] Research Hydraulic Engineer, Coastal and Hydraulics Laboratory, WES.
[2] President, Water Resources Planning and Restoration, Utica, MS 39175-0351; formerly Wildlife Biologist, Environmental Laboratory, WES.

filling, and handling the tubes. After responding to numerous requests for assistance in this regard, and realizing that information is exceedingly limited regarding geotextile tube structures, WES developed a workshop to document recent experiences with geotextile tubes (Davis and Landin 1997). Discussions at the workshop focused on specific case studies, experiences with deploying and filling tubes, hydrodynamic and geotechnical engineering design, geotextile fabric characteristics, and risk and contingency planning. Fifty participants at the workshop came from USACE Headquarters, Districts and laboratories, the Port of Houston Authority, academia, engineering consulting firms, material suppliers, and dredging contractors. The workshop was held in Galveston, Texas, 15-17 August 1995, and was hosted by the U.S. Army Engineer District, Galveston. The workshop was cosponsored by the USACE Wetlands Research Program, Dredging Research Program, and Dredging Operations Technical Support Program, all of which were conducted by and managed at WES.

The workshop produced two significantly important deductions; (a) limitations of geotextile tubes were identified, and (b) criteria for geotextile tube applications were developed. It was determined that, in general, geotextile tubes have worked well for wetlands restoration and protection projects. Geotextile tubes discussed at the workshop are basically two sheets of fabric sewn together along their edges and filled with dredged material. More complicated tube designs have been used, but the more complicated the design, the more expensive it is to manufacture and utilize. Fine-grained sediments have been used as filler for tubes, but post-construction consolidation of the fill material can become a problem unless alternative measures to alleviate such situations are anticipated in advance. Unless otherwise noted, it was assumed that sand was used as the filler material.

Limitations of Geotextile Tubes

Concerns raised at the workshop were the same as those previously promulgated by Pilarczyk (1995) in his review of "novel" systems for coastal engineering. Participants were concerned about; (a) fabric resistance to puncture and abrasion, (b) fabric degradation in the environment, especially due to ultraviolet (UV) light exposure, (c) difficulty with placing a tube precisely on alignment, (d) difficulty with achieving a consistent crest height along the length of the tube, and (e) lack of hydraulic, hydrodynamic, and geotechnical design guidance.

Experience indicates geotextile tube resistance to punctures and abrasion is low. Puncturing the material with a blunt object (e.g., bow of a boat) is not easy; however, it takes little effort to puncture even the highest strength material (e.g., 1,000 lb/in. tensile strength) with a sharp object like a knife. Consequently, in almost any area where the public has had easy access, the tubes have been vandalized (possibly from curiosity about what is inside). Debris (e.g., a stump with pointed roots) that is forced against the tube by waves or currents may puncture and abrade the material and, although it was not reported at the workshop, participants suspected that ice could also abrade or puncture the fabric. The fabric also can be abraded during shipping and handling, and during deployment. For example, tubes deployed off the deck of a barge could be torn by any sharp edge or protrusion on the deck. Tubes have been damaged by equipment (e.g., dredge pipe flanges) that was dragged across the tubes during construction. Workshop participants noted that torn tubes will usually lose sediment only within a few feet on either side of the tear. Most of the tube beyond the damaged section will remain intact.

Fabric degradation rates due to natural UV light are unknown. Laboratory tests exposing fabrics to intense UV radiation have been conducted and the results suggest that the fabric is resistant to a degree, but the results cannot be extrapolated to actual field applications. Some workshop participants suggested that tubes could last several decades (20-50 years) in the field, but others contended that without data, an estimate of 10-20 years might be better for planning. Since the workshop, tubes (originally 400 lb/in. tensile strength) have been inspected along the Texas coast, and it is suspected that the tubes are tearing where fabric has been weakened by sunlight (Figure 2). This particular tube is 4 years old and is exposed to

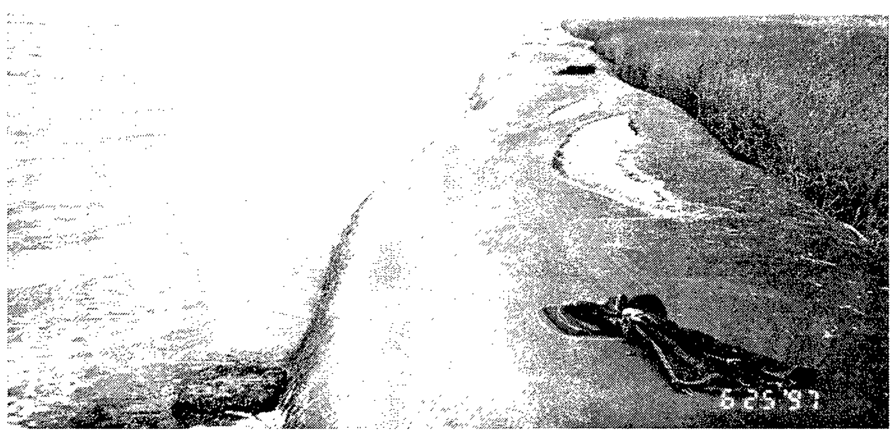

Figure 2. Geotextile tube tears due to ultraviolet sunlight damage

sunlight most of the time. The effect of ultraviolet light is significantly reduced or eliminated when tubes are submerged or covered by sediments and marine growths.

The constructed quality (final height and alignment) of the tube depends on the skill of the construction contractors, the quality of the fill material, and the environmental conditions under which the deployment and filling take place. The skill and experience of some contractors are increasing within the dredging industry, but no method has yet been widely accepted or documented as the best approach to deploy and fill tubes. If fill material is used that consolidates over time, the height of the tube will decrease over time, possibly to a height that is insufficient for the tube's intended purpose. Deploying tubes in waves and currents can make holding the tubes on a given alignment very difficult. If the tube is not placed directly on a given bed elevation, variations in the bed elevation can cause variations in the tube crest elevation. Also, a tube may twist (roll slightly) to one side during filling. When such a twist occurs, it moves off alignment, and puts the filling ports to the side of the tube instead of on top. Figure 3 shows the variation in crest elevation along a tube and from one tube to the next. In the foreground, the filling port is seen off-center, suggesting that the tube may have rolled slightly during filling. Figure 4 shows the variability in the alignment of a tube.

Some variations of crest height cannot be avoided. If the contractor stops filling a tube prematurely, because of weather, for example, sand in the tube will stabilize and tend to flatten the tube. Once that happens, it is very difficult to pump the tube up higher. Also, low spots always occur near the filling ports, with random undulations elsewhere. It is not surprising to find variations of one-half foot or more along the length of the tube. Based on conclusions from the workshop, it is expected that more than 5 ft in final tube height cannot readily be achieved regardless of the size of the tube used. Greater final tube height may be possible to achieve, but it has not been the dominant experience of the workshop participants.

Existing guidance is limited for designing and predicting the stability of tube structures. Some techniques modified from other structure design criteria were discussed at the workshop. It was suggested that the U.S. Army Corps of Engineers (1984) or Minikin (1983) methods for predicting loads on vertically faced structures could be used. Similarly, techniques recommended by Goda (1985) and Walton et al. (1989) could be used. The resisting forces (bed friction and weight) can be estimated. A force balance will then indicate whether the tube is likely to move due to wave and current loading. Suggested friction angles provided at the workshop are 18 deg for fabric on fabric (i.e., stacked tubes) and 25 deg for fabric on sand. WES maintains a discrete- element model that can be used to simulate the deformation of a tube in two-dimensional cross section under loading. Sprague (1995) offers a graphical technique for estimating the strength of fabric needed for an application. Most participants agreed that if there is concern about the strength of the fabric, then stronger fabrics should be utilized (fabrics with at least 1,000 lb/in. fabric tensile strengths are available). Sprague (1995) also presents a technique for selecting the spacing for filling ports along the crest of the tube. However, all of the approaches discussed in the literature disregard the three-dimensional nature of the tubes.

Criteria for Geotextile Tube Applications

Based on the limitations of geotextile tubes and the assembled experiences of the participants, general criteria were compiled that can be used to indicate appropriate applications for geotextile tubes. (Pilarczyk (1995) also identifies several of these criteria). The criteria essentially state the conditions under which the participants noted successes in geotextile tube projects. The criteria may not be entirely complete, but will serve as a fundamental guide for geotextile tube siting applications. The criteria list is not prioritized.

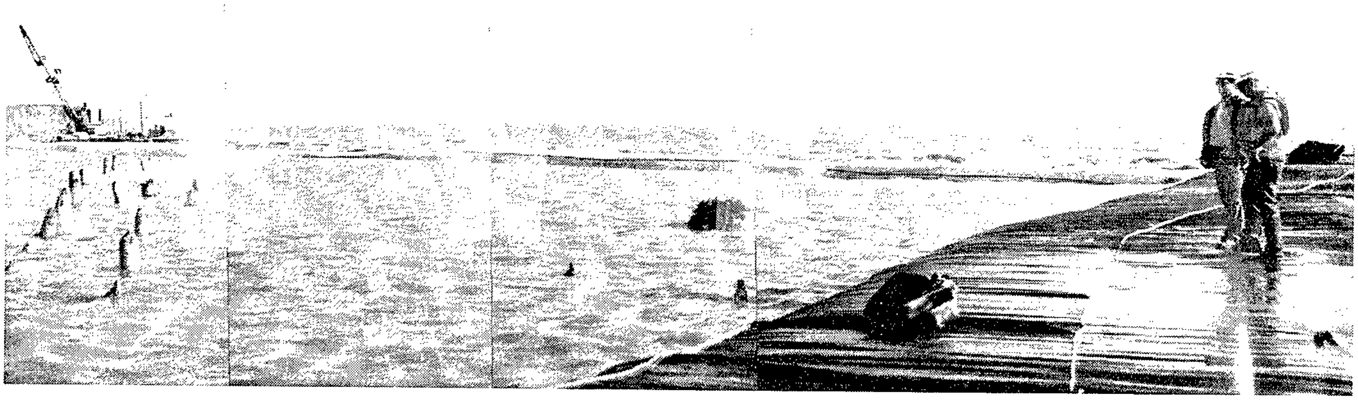

Figure 3. Variation in crest elevation along a geotextile tube, and from one tube to the next

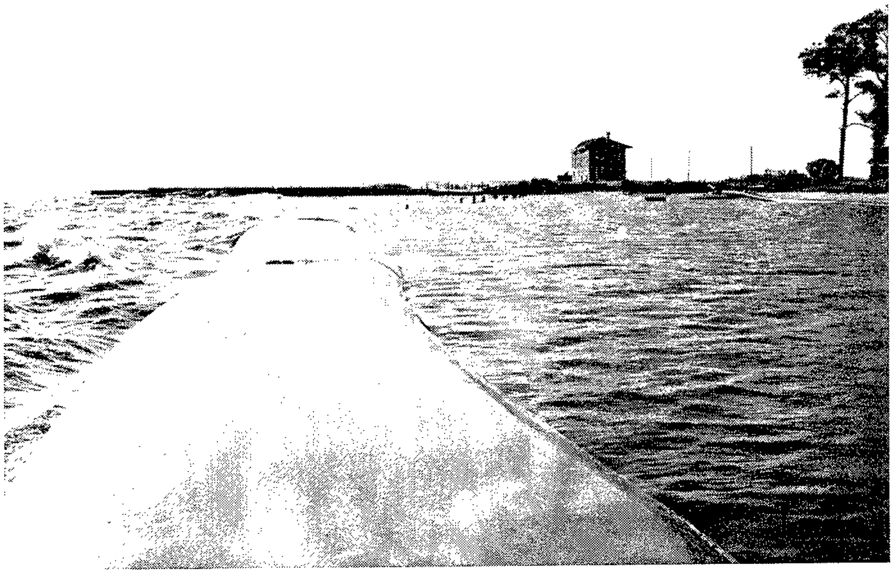

Figure 4. Variation in the alignment of a geotextile tube

- **Shallow Water, Low Tidal Range, Low Wave Energy:** Tubes have been used successfully where water depths are small (<3 ft), where the tidal range is small (<3 ft), where fetches are less than 15 miles, and where the depth for a considerable distance offshore is less than 10 ft. Wave climate is low in these areas, so the large mass of the tubes makes them very stable.
- **Temporary:** A good use for a geotextile tube is as a temporary structure, although this utilization carries several implications. First, a tube could be ideally used as a truly temporary structure. Tubes have been placed as groins to prevent the possible migration of beachfill sand into a nearby bed of sea grass. There was great uncertainty regarding which way sand from the project would migrate. Rather than spend money studying the coastal processes in this very small area, the groin was installed as a precaution. After construction of the beachfill, the real transport characteristics of the site could be readily observed. Second, a temporary tube could be one that has scheduled maintenance (i.e., it will be repaired or replaced when damaged). Third, a temporary tube could be hidden and only become effective during certain conditions. Geotextile tubes have been buried in the berm or dune of a beach and only become effective when erosion exposes them (for instance, during a storm). Once exposed, maintenance is usually required to repair and/or rebury it. A hidden tube is not exposed to vandalism or debris damage, and it blends into the environment well.
- **No threat to life or property:** Geotextile tubes are effective structures as long as they remain intact but, since their durability is uncertain, depending on them to protect life or property for long periods of time (without maintenance) is not recommended. A good application, then, is one where no risk to life or property exists should the tube fail.
- **Flexible height and alignment requirements:** Since aligning geotextile tubes during placement and achieving consistent crest elevation along the length of the tubes may be very difficult, the best applications for geotextile tubes are where variations in these parameters are tolerable.
- **Associated with an existing dredging project:** The growing popularity of geotextile tubes is due to several factors, the main one being that they are usually less expensive than other protection or containment alternatives. Geotextile tubes are most cost-effective when used in conjunction with a dredging project because the cost of mobilizing a dredge to fill the tubes is minimized. The cost of tube construction is maximized when a dredge has to be mobilized on short notice to fill a small section of tube.

Success in Wetlands Restoration Protection

USACE has constructed wetlands restoration projects on disposed dredged material using geotextile tubes as containment dikes and for erosion protection in the Chesapeake Bay near Smith Island, Barren Island, the Pokomoke River, and Eastern Neck National Wildlife Refuge, along the Gulf Intracoastal Waterway in West Bay north of Galveston Island, and near the Aransas National Wildlife Refuge in Texas. These wetlands restoration projects were initiated in areas where wetlands once existed. The areas are generally in shallow water with low tidal ranges and, consequently, low wave energies. Because the area in the lee of the structures is intertidal marsh, the tubes were built to low elevations so that they would be sufficient to protect the root mat of the marsh from erosion. The naturally low and wide cross-sectional shape of a geotextile tube makes it stable and suitable for this application. Figure 5 is an aerial view of one of the projects near the Aransas National Wildlife Refuge.

Low wave energy conditions limit the amount of toe scour that occurs at the tube. A tube should have a geotextile scour apron to prevent toe erosion. The aprons placed at some USACE structures have performed well, suffering little or no damage after several years of service. Some have silted over. However, it is likely that in higher wave energy environments, the apron would not be as effective except perhaps as a temporary measure. Any other type of apron (e.g., stone or concrete) would increase the

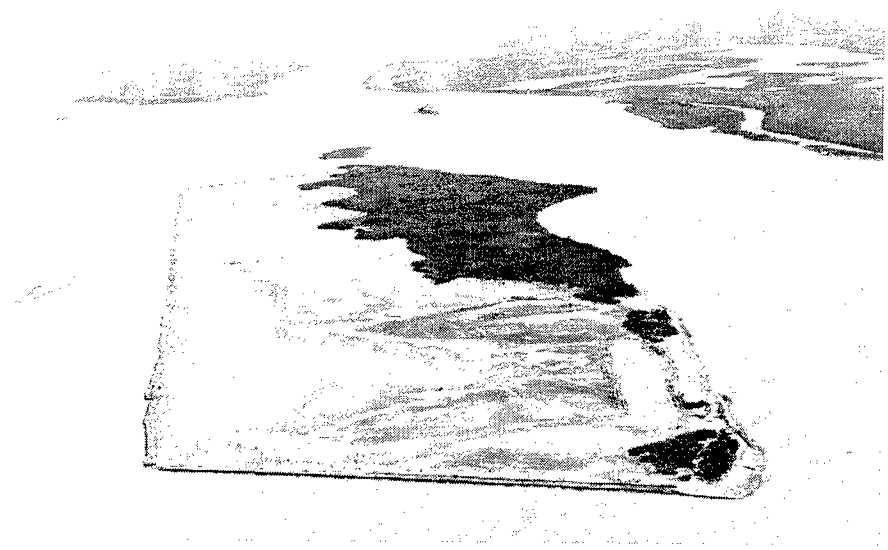

Figure 5. Use of geotextile tubes in wetlands restoration project, Aransas National Wildlife Refuge, Texas

cost of the project and may damage the tube fabric.

The tubes used in the USACE wetland projects are not necessarily temporary or hidden, but could be maintained. The projects are near navigation channels, so the opportunity for maintenance during subsequent dredging cycles is readily available. The projects are in remote areas of bays where public access is difficult, so the risk of vandalism is low. However, the potential for damage due to debris is always present.

Remoteness of the wetland projects inherently satisfies the criterion that no life or property be at risk in the event of tube failure. The only thing at risk if the geotextile tube is damaged is potential erosion of a portion of the wetland that was restored. Such erosion may actually be ecologically desirable. After the wetlands have developed behind the geotextile tubes, it is often desirable to open up the area to the ingress and egress of marine organisms. Removal of a tube is an option. Furthermore, when part of the wetland is eroded, it often remains as shallow open water or as a mud flat, both of which provide diversity of habitat.

Random height variations along the length of a geotextile tube cause a varying amount of wave transmission into the marsh along the tube. This varying wave energy results in a somewhat random and natural-looking plant growth and propagation pattern in the lee of the tubes.

All the USACE wetland projects have been associated with existing maintenance dredging where the maintenance material was to be used beneficially. Geotextile tubes provided a means for containing the material and protecting the marsh from erosion in a cost-effective manner. If the projects had been developed separately from maintenance dredging, the costs for the projects would have been excessive.

Conclusions

Geotextile tubes are being considered by the U.S. Army Corps of Engineers for alternative structure designs at several different applications. Many of these uses severely challenge designers because of the limitations of geotextile tubes. They can be punctured and abraded easily by vandals, debris, and ice; their life expectancy after prolonged exposure to UV light is unknown; and they are difficult to construct to precise alignment and crest elevations. Yet, used as temporary structures, as hidden components of structures, in shallow water with low wave energy and tidal regimes, on projects where there is no risk to life or property in the event of failure, on projects where inspections and maintenance will be established, and/or on projects where sand is being dredged, geotextile tubes can be very effective.

Wetlands restoration projects developed on dredged material placed to intertidal elevations satisfy many criteria necessary for successful geotextile tube application. If funds are available to develop a marsh habitat, the relatively low costs of geotextile tubes makes them an attractive alternative for erosion protection and dredged material containment. Costs for placement of geotextile tubes in several Texas projects varied from $50 to $100 per linear foot. In projects where a dredge was mobilized to fill a short tube, costs approached $200 per linear foot. Geotextile tube containment dikes were generally more expensive than unprotected earthen dikes, but less expensive than an equivalent riprap structure.

Pilarczyk (1995) notes that many worthwhile applications for geotextile tubes exist, but they should not be considered for general coastal engineering applications. The criteria identified at the national workshop, though not all-encompassing, may serve as a reasonable guide because they avoid or minimize the effects of geotextile limitations. While the construction of geotextile tubes is conceptually easy to understand, it should be remembered that these are massive structures. Therefore, to have a successful project, foundation, scour, overtopping, and flanking protection must be given great consideration in design.

References

Davis, J. E., and Landin, M. C. 1997. "Proceedings of the national workshop on geotextile tube applications," Technical Report WRP-RE-17, U.S. Army Engineer Waterways Experiment Station, Vicksburg, MS.

Goda, Y. 1985. "Random seas and design of maritime structures," University of Tokyo Press, Tokyo, Japan.

Minikin, R. R. 1963. "Winds, waves and maritime structures: Studies in harbor making and in the protection of coasts," 2nd rev. ed., Griffin, London.

Pilarczyk, K. W. 1995. "Novel systems in coastal engineering: Geotextile systems and other methods, an overview," HYDROpil Report, Road and Hydraulic Engineering Division of the Rijkswaterstaat, Delft, The Netherlands.

Sprague, J. C. 1995. "P.E.T. Geotextile Tubes and Containers for Beneficial Use of Dredged Material," Draft Contract Report for Bradley Industrial textiles, Inc., Valparaiso, FL, and Hoechst Celanese Corporation, Spunbond Business Group, Spartanburg, SC.

U.S. Army Corps of Engineers. 1984. "*Shore Protection Manual*," Volume II, 4th ed., U.S. Government Printing Office, Washington, DC.

Walton, T. L., Ahrens, J. P., Truitt, C. L., and Dean, R. G. 1989. "Criteria for Evaluating Coastal Flood-Protection Structures," Technical Report CERC-89-15, U.S. Army Engineer Waterways Experiment Station, Vicksburg, MS.

Coastal Zone '99

The U.S. Army Engineer Waterways Experiment Station is a co-sponsor of **Coastal Zone'99; The People, The Coast, The Ocean - Vision 2020.** Currently, about 2.5 billion people live within 100 km of the world's coastal margins. That number will grow to more than 6 billion by the year 2050. Impacts and demands stemming from this population growth will put enormous pressure on coastal and ocean resources. **Coastal Zone '99** invites abstracts on the following themes; human dimension, ocean realm, watershed perspective, and public connection. The **human dimension** will examine how coastal zone management affects people and why people should care about what happens to the coasts and oceans (e.g., economic implications, human health impacts, public interest and private property rights, and religious, philosophical, and cultural considerations). The **ocean realm** will focus on the world's major seas, including the Great Lakes, and examine the environmental conditions of the ocean and lakes, the status of exploration and research, and strategies to effectively protect and restore the living resources of the oceans and lakes. The **watershed perspective** relates to the upland dimension of the coastal zone and will look at the complex management problems that arise in watersheds where we all affect—and are affected by—the land and water use practices of others (e.g., run-off pollution, cross-boundary issues, habitat restoration and mitigation, ports and harbors, urban redevelopment, coastal hazards). The **public connection** will probe how to achieve greater levels of public involvement in the planning and implementing of management solutions through activities that increase public awareness (e.g., public education, volunteer activities, advocacy and advisory functions, and political activism).

Coastal Zone '99 will be held 24-30 July 1999 in San Diego, California. Abstracts are invited for oral or poster presentations. In addition to submission of individual abstracts, proposals are invited for special sessions, roundtable discussions and workshops. Special sessions that focus on one particular topic and reflect the conference themes may be organized in coordination with the program committee. Roundtable discussions that reflect the conference themes will be held during lunchtime. Interactive workshops that reflect conference themes may also be organized in coordination with the program committee. All abstracts should be received by 1 August 1998, and are subject to peer review. Additional information may be obtained from Martin Miller, CZ99 Co-Chairman, e-mail m.miller@cerc.wes.army.mil, or cz99@umbsky.cc.umb.edu, or on the Internet at http://omega.cc.umb.edu/~cz99.

Pacific Coasts and Ports '97 Proceedings Available

Proceedings of the 13th Australasian Coastal and Ocean Engineering Conference and 6th Australasian Port and Harbour Conference (Pacific Coasts and Ports '97) are now available. The 2-volume Proceedings contains 180 papers covering a wide range of topics from authors in 18 countries around the Pacific Rim. The scope of the conference reflects the increasing requirement for managers to move toward a multi-disciplinary approach involving engineering, scientific, planning, and resource management disciplines when addressing coastal zone problems. The peer-reviewed papers contained in the Proceedings cover the spectrum from ecological monitoring of the marine environment through the design and construction of ports and coastal structures. The authors are a well-balanced mix of professionals representing national and local governments, academic institutions, and private industry. The Proceedings can be obtained from John Lumsden, Chairman, Center for Advanced Engineering, University of Canterbury, Private Bag 4800, Christchurch, New Zealand.

The Waterways Committee of the American Society of Civil Engineers recently held their annual meeting at the Waterways Experiment Station, Coastal and Hydraulics Laboratory (CHL). Charles Calhoun, Assistant Director, CHL, member and past chairman of the Committee, hosted the meeting. In addition to conducting their Committee business, Committee members toured facilities at WES. Members attending were (from left to right) front row: B. K. Lee, Harza Engineering Company; Al Wortley, University of Wisconsin; Ray Montgomery, Ray Montgomery Associates; Mr. Calhoun; back row: Paul Schonfeld, Committee Chairman, University of Maryland; Craig Fischenich, WES; Bruce McCartney, retired, Corps' North Pacific Division; and Mark Lindgren, Corps' Walla Walla District.

Calendar of Coastal Events

Aug 3 - 7, 1998	**1998 International Water Resources Engineering Conference and Symposia,** Memphis, TN, USA, POCs: **Conference,** Steven R. Abt, Engineering Research Center, Colorado State University, Fort Collins, CO 80523, phone 970-491-8203, fax 970-491-8462; **Groundwater Symposium,** John W. Smith, Ground Water Institute, University of Memphis, Memphis, TN 38152, phone 901-678-3283, fax 901-678-3026; **Wetlands Symposium,** Lisa C. Roig, USAE Waterways Experiment Station, ATTN: CEWES-HH-W, 3909 Halls Ferry Road, Vicksburg, MS 39180, phone 601-634-2801, fax 601-34-4208; **Bank Stabilization Symposium,** David S. Biedenharn, USAE Waterways Experiment Station, ATTN: CEWES-HH-W, 3909 Halls Ferry Road, Vicksburg, MS 39180, phone 601-634-4653, fax 601-634-2823.
Aug 22 - 28, 1998	**World Deltas Symposium,** New Orleans, LA, USA, POC: James M. Coleman, email chanjc@lsuvm.sncc.lsu.edu, http://opal.ga.lsu.edu/deltas98
Aug 24 - 26, 1998	**Hydroinformatics '98,** Copenhagen, Denmark, POC: Danish Hydraulic Institute, Agern Alle 5, DK-2970 Horsholm, Denmark, phone +45 45 76 95 55, fax +45 45 76 25 67, email HIC98@dhi.dk, http://www.dhi.dk/HIC98/Welcome.html
Aug 25 - Sep 11, 1998	**MEDCOAST Institute '98, The 4th International Training Program on Integrated Coastal Management in the Mediterranean and the Black Sea**, Ankara-Marmaris-Cappadocia, Turkey, POC: MEDCOAST Secretariat, Middle East Technical University, 06531 Ankara, Turkey, phone (90 312) 210 54 29/40/30/35, fax (90 312) 210 14 12, e-mail medcoast@rorqual.cc.metu.edu.tr
Aug 30 - Sep 3, 1998	**Coastal Zone Canada '98,** Victoria, British Columbia, Canada, POC: Coastal Zone Canada '98, Conference Management, Division of Continuing Studies, University of Victoria, Box 3030, Victoria, British Columbia, Canada V8W 3N6, phone (250)721-8470, fax (250)721-8774, http://www.ios.bc.ca/ios/czc98/
Aug 31 - Sep 3, 1998	**3rd International Conference on Hydroscience and Engineering,** Cottbus/Berlin, Germany, POC: Conference Secretariat, M. W. Raschke or A. Groba, Brandenburg University of Technology at Cottbus, Institut fuer Bauinformatik, Karl-Marx-Strasse 17, D-03044 Cottbus, Germany, phone/fax 49-355-69-2262, e-mail lfb@bauinf.tu-Cottbus.de, http://www.bauinf.tucottbus.de/ICHE98/Welcome.html
Sep 6 - 11, 1998	**PIANC 29th International Conference: Permanent International Association of Navigation Congresses,** The Hague, Netherlands, POCs: The Hague, phone 32 2 208 5216, fax 32 2 208 5215, Thomas M. Ballentine, US Section PIANC, Casey Bldg., 7701 Telegraph Road, Alexandria, VA 22315-3868, phone (703) 428-7072, fax (703) 428-8171.
Sep 8 - 10, 1998	**Coastal Environment '98; 2nd International Conference, "Environmental Problems in Coastal Regions,"** Cancun, Mexico, POC: Secretariat, Wessex Institute of Technology, Ashurst Lodge, Ashurst, Southampton, UK SO40 7AA, phone 44-1703-293-223, fax 44-1703-292-853, email iz@wesses.ac.uk, http://www.wessex.ac.uk
Sep 21 - 25, 1998	**8th Congress, International Association of Engineering Geology; A Global View from the Pacific Rim,** Vancouver, BC, Canada, POC: Ms. Kim Meidal, email kim.meidal@bchydro.bc.ca
Oct 5 - 7, 1998	**American Shore and Beach Preservation Association National Conference,** Galveston, TX, USA, POC: Sally Davenport, Associate Deputy Commissioner, Resource Management, Texas General Land Office, 1700 North Congress Avenue, Austin, TX 78701-1495.
Oct 5 - 7, 1998	**Fifth International Conference on Remote Sensing for Marine and Coastal Environments,** San Diego, CA, USA, POC: ERIM/Marine Conference, P.O. Box 134008, Ann Arbor, MI 48113-4008, phone 313-994-1200 ext. 3234, fax 313-994-5123, email marine@erim-int.com, internet http://www.erimint.com/CONF/marine/MARINE.html
Oct 21 - 23, 1998	**Florida Shore and Beach Preservation Association, 43rd Annual Meeting,** Captiva Island, FL, USA, POC: Stan Tait, phone 904-222-7677.
Oct 21 - 23, 1998	**Docks and Marinas '98, Marina Design for the 21st Century,** Madison, WI, USA, POC: Professor C. Allen Wortley, Course Directory, University of Wisconsin, 432 North Lake Street, Suite 807, Madison, WI 53706-1498, phone 608-263-3160, email wortley@engr.wisc.edu
Oct 26 - 30, 1998	**Fundamentals of Coastal Engineering,** Vicksburg, MS, USA, POC: Jim Clausner, U.S. Army Engineer Waterways Experiment Station, Coastal and Hydraulics Laboratory, Vicksburg, MS 39180, phone (601)634-2009, fax (601)634-3080, email j.clausner@cerc.wes.army.mil

US Army Corps
of Engineers
Waterways Experiment
Station

The Corps' Coastal Vision Statement

We will, as the National Coastal Engineer:

- **Continue our leadership in the protection, optimization, and enhancement of the Nation's coastal zone resources.**
- **Increase our contribution to the Nation's economy, quality of life, public safety, and environmental stewardship.**

The **CERCular**

Coastal Engineering Research Center

This bulletin is published in accordance with AR 25-30 as an information dissemination function of the U.S. Army Engineer Waterways Experiment Station. The publication is part of the technology transfer mission of CERC (an entity within the Coastal and Hydraulics Laboratory of WES) under PL 79-166 and PL 99-802. Results from ongoing research programs will be presented. Special emphasis will be placed on articles relating to application of research results or technology to specific project needs. Additional information and the CERCular can be found through the CHL Homepage at:

http://bigfoot.cerc.wes.army.mil/CERC_homepage.html

Contributions of pertinent information are solicited from all sources and will be considered for publication. Communications are welcomed and should be addressed to the U.S. Army Engineer Waterways Experiment Station, Coastal and Hydraulics Laboratory, ATTN: Dr. Lyndell Z. Hales, 3909 Halls Ferry Road, Vicksburg, MS 39180-6199, or call (601) 634-3207, FAX (601) 634-4253, Internet: l.hales@cerc.wes.army.mil

ROBERT W. WHALIN, PhD, PE
Director, WES

PRINTED ON RECYCLED PAPER

DEPARTMENT OF THE ARMY
WATERWAYS EXPERIMENT STATION, CORPS OF ENGINEERS
3909 HALLS FERRY ROAD
VICKSBURG, MISSISSIPPI 39180-6199

OFFICIAL BUSINESS
CEWES-CV-I